Updating Key Definitions Related Chemical Recycling

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Overview

EPA is proposing to update existing and develop new definitions used to characterize generation and management of

Existing Definitions (Industry/Stakeholder Groups)

- Advanced recycling, also called "chemical recycling," refers to several different processes that use existing and emerging technologies that return post-use plastics to their basic chemical building blocks for creating a versatile mix of new plastics, chemicals, fuels, and other products. The outputs from chemical recycling can include virgin plastics, specialty chemicals, basic building blocks (monomers), chemical feedstocks (naptha), fuels and other products (e.g. waxes). The terms advanced recycling and recovery, transformational technologies, and chemical recycling, are interchangeable. All of these terms help differentiate advanced recycling from the more widely known recycling processes that use mechanical technologies to recycle used plastics. [HYPERLINK "https://plastics.americanchemistry.com/what-is-chemical-recycling/"]

- Chemical recycling of polymer waste is defined as any reprocessing technology that directly affects either the formulation of the polymeric material or the polymer itself and converts them into useful products like monomers, basic-chemicals, alternative fuels and other value-added materials. ([HYPERLINK "https://www.chemicalrecyclingeurope.eu/about-chemical-recycling"])

- Chemical recycling alters the physical state of the plastic, returning the material to its constituent parts (or building blocks) and thus a more purified (or "virgin") form, by dissolving it in chemicals or breaking it down it with heat. It can then be returned to the industry and made into brand-new, high-quality plastic objects. ([HYPERLINK "https://www.newsweek.com/chemical-recycling-plastic-waste-virgin-state-1485648"])

- Chemical recycling breaks down plastic polymers into their chemical building blocks, so they can be used all over again to make virgin plastic without losing any properties." ([HYPERLINK "https://www.bath.ac.uk/announcements/new-way-of-recycling-plant-based-plastics-instead-of-letting-them-rot-in-landfill/"])

- Chemical recycling often refers to technologies that can be classed depending on the level at which they break down the plastic waste. This can include solvent-based purification, chemical depolymerization, and thermal depolymerisation and cracking (pyrolysis and gasification)

Technologies

Depolymerization

- Solvent-based purification. Comprises of technologies that go down to the polymer stage. They are capable of decontaminating the plastic but cannot address its degradation. They work only with mono streams (PVC, PS, PE, PP). ([HYPERLINK "https://circulareconomy.europa.eu/platform/en/knowledge/el-dorado-chemical-recycling-state-play-and-policy-challenges"])

  Chemical de-polymerisation. Chemical process which turns the plastics back into their monomers. Allows for decontamination but not addressing degradation. Only works with mono streams (PET, PU, PA, PLA, PC, PHA, PEF). ([HYPERLINK "https://circulareconomy.europa.eu/platform/en/knowledge/el-dorado-chemical-recycling-state-play-and-policy-challenges"])

Energy Recovery

General

- [HYPERLINK "https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw"] from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE). Converting non-recyclable waste materials into electricity and heat generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills. After energy is recovered, approximately ten percent of the volume remains as ash, which is generally sent to a landfill. ([HYPERLINK "https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy"])

- Gasification, plasma gasification and pyrolysis—are considered "conversion technologies," which are technologies that do not involve combustion (burning with oxygen). They super-heat solid waste in low-oxygen environments, which greatly reduces the production of toxic emissions, and facilitates the immediate recovery of metals and slag so less residue goes to landfills and that which remains is less toxic. ([HYPERLINK "https://blogs.ei.columbia.edu/2016/10/18/putting-garbage-to-good-use-with-waste-to-energy/"])

- Thermal de-polymerisation and cracking (pyrolysis and gasification) are energy-intensiveare energy-intensive processes, which turn the polymers back into simpler molecules. They are capable of decontaminating polymers and, by bringing plastic back to its original building blocks, addressing the degradation of the material. These technologies can deal with more than one monomer at a time and are also capable of producing fuels. This raises the need for strict regulatory controls to prevent plastic being turned into fuel in lieu of recycling.

Specific Technologies

Gasification:

- Gasification is the partial oxidation of carbon-based feedstock to generate syngas. The process is similar to pyrolysis, except that oxygen (as air, concentrated oxygen, or steam) is added to maintain a reducing atmosphere, where the quantity of oxygen available is less than the stoichiometric ratio for complete combustion. Gasification forms primarily carbon monoxide and hydrogen, but potentially other constituents such as methane particularly when operating at lower gasification temperatures. Gasification is an endothermic process and requires a heat source, such as syngas combustion, char combustion, or steam. The primary product of gasification, syngas, can be converted into heat, power, fuels, fertilizers or chemical products, or used in fuel cells. The current main types of gasification processes for MSW include the following:

    - ***High temperature gasification***—High temperature gasification reactors, as described in ARI (2007), can reach up to 1,200 °C and produce an inert byproduct, or slag, that does not need further processing to be stabilized. The syngas is typically combusted to generate steam which can be used for power and/or heat generation; however, the resultant sysngas may also be used for other applications such as chemicals production. Typically, this technology processes a mix of carbonaceous waste including paper, plastics, and other organics with a moisture content of up to 30 percent, which avoids the need for drying. In general, there are no water emissions because conventional water treatment systems are used to convert process discharges to useable process and/or cooling water. Treatment systems include settling and precipitation to capture and remove solids, which are returned to the high-temperature reactor.

    - ***Low temperature gasification***—Low temperature gasification reactors, as described in ARI (2007) and RTI (2005), operate at temperatures between 600 and 875 °C and produce ash that could be sent to a vitrification process to make it inert and available for other uses. Syngas is the main product from this process and is typically used for electricity generation using an Internal Combustion Engine (ICE). This process can also recover steam energy. Separate estimates of energy from syngas and steam are obtained. This technology is assumed to require a feedstock with a moisture content of 5 percent or less and includes a drying pre-processing. A mix of gases and aerosols are produced from low temperature gasification and are sent to be quenched. The resulting liquid is cooled and water is recovered and sent to a solids mixing tank. Char, brine, and bio-oils may also be recovered. Bio-oils are typically recycled back to the process, but may be useful as fuel intermediates, and char and brine are included as water and solid waste emissions.

    - ***Plasma gasification***—Plasma gasification converts selected waste streams including paper, plastics, and other organics, hazardous waste, and chemicals to syngas, steam, and slag. In this technology, the gasification reactor uses a plasma torch where a high-voltage current is passed between two electrodes to create a high-intensity arc, which in turn rips electrons from the air and converts the gas into plasma or a field of intense and radiant energy with temperatures of thousands of degrees Celsius. The heated and ionized plasma gas is then used to treat the feedstock. Material such as petroleum coke is sometimes added to the reactor to support reduction reactions and to stabilize the slag. No drying pre-processing of the feedstock is required and the feedstock is assumed to have up to 30 percent moisture content. Syngas and steam are then typically used for power generation, included in the estimate of total electricity offsets. The slag, also produced in this process, is quenched prior to any use or disposal.

- As with pyrolysis, residues such as slag and ash that are produced in the gasification process may need to be disposed of at a landfill. Another potential issue that may need to be assessed is the level of pre-sorting necessary. Some pre-processing will be needed for many of these facilities. For some gasification technologies, however, a significant presorting process will be required, including the removal of recyclables, sorting, shredding, and drying. The pre-sorting process is necessary to make the feedstock more homogenous and to increase efficiency of the overall process. ([HYPERLINK "https://nepis.epa.gov/Adobe/PDF/P100FBUS.pdf"])

Pyrolysis:

- Pyrolysis is defined as an endothermic process, also referred to as cracking, involving the use of heat to thermally decompose carbon-based material in the absence of oxygen. Its main products are a mixture of gaseous products, liquid products (typically oils of various kinds), and solids (char and any metals or minerals that might have been components of the feedstock). Technologies that are categorized as pyrolysis generally belong to one of the following process categories:

  - ***Thermal pyrolysis/cracking***—The feedstock is heated at high temperatures (350–900 degree Celsius) in the absence of a catalyst. Typically, thermal cracking uses mixed plastics from industrial or municipal sources to yield low-octane liquid and gas products. These products require refining to be upgraded to useable fuel products.

  - ***Catalytic pyrolysis/cracking***—The feedstock is processed using a catalyst. The presence of a catalyst reduces the required reaction temperature and time (compared to thermal pyrolysis). The catalysts used in this process can include acidic materials (e.g., silica-alumina), zeolites (e.g., HY, HZSM-5, mordenite), or alkaline compounds (e.g., zinc oxide). Research has shown that this method can be used to process a variety of plastic feedstocks, including low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS). The resulting products can include liquid and gas products.

  - ***Hydrocracking*** (sometimes referred to as "hydrogenation")—The feedstock is reacted with hydrogen and a catalyst. The process occurs under moderate temperatures and pressures (e.g., 150–400 °C and 30–100 bar hydrogen). Most research on this method has involved generating gasoline fuels from various waste feedstocks, including MSW plastics, plastics mixed with coal, plastics mixed with refinery oils, and scrap tires.

  - The process of pyrolysis creates residues including char, silica (sand), and ash. Some of these residues may be reused (if approved by an environmental agency) while others must be disposed of in a landfill. ([HYPERLINK "https://nepis.epa.gov/Adobe/PDF/P100FBUS.pdf"]

- Plastic Pyrolysis is a chemical reaction. This reaction involves the molecular breakdown of larger molecules into smaller molecules in the presence of heat. Pyrolysis is also known as thermal cracking, cracking, thermolysis, depolymerization, etc. [HYPERLINK "https://www.pyrolysisplant.com/what-is-pyrolysis"].

Anaerobic Digestion

- AD is a biochemical conversion process that decomposes organic material in the absence of oxygen (O_2). Organic waste materials such as manure, agricultural wastes, and biodegradable fractions of industrial, commercial, and MSW (or fractions of MSW) can be used as feedstocks for anaerobic digesters. The main product of AD is a methane-rich biogas, which can be combusted to generate heat and/or electricity, converted to pipeline quality gas, or further refined to create biomethane, a transportation fuel. Byproducts of AD include CO_2 and undigested solids. Depending on the type of feedstock used, the undigested solids may have economic value when refined and used as a fertilizer soil amendment.